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RECONNAISSANCE REPORT ON PAPILLION CREEK RESERVOIRS.(U)
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Most algal control methods considered in this report are short term in nature and must be frequently applied for continued success. New methods of biological control show good potential but are not yet generally applicable.

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RECONNAISSANCE REPORT ON PAPILLION CREEK RESERVOIRS [1]

INTRODUCTION

The purpose of this reconnaissance report is to evaluate the potential problems associated with establishing recreational facilities at the proposed Papillion Creek Reservoirs near Omaha, Nebraska. Data on the limnology of existing reservoirs in eastern Nebraska and western Iowa were compiled. Seven of the eight existing reservoirs studied were eutrophic and exhibited characteristics detrimental to water-related recreation. Based on the data available, waterbased recreation at the Papillion Creek Reservoirs will probably be of marginal quality. Turbid water, weed infestation and excessive algal blooms are all realistic problems.

The primary purpose of this report is to determine the extent to which aquatic weed growth may interfere with the recreational use of the flood control and recreational reservoirs authorized for Papillion Creek near Omaha, Nebraska. Rooted aquatic plant growth is only one aspect of reservoir limnology. Water quality, siltation and algal growth are also important considerations in evaluating water-related recreation. Therefore, this report is not limited to weed infestation. Chemical, physical and biological characteristics of reservoirs are discussed relative to eutrophication of the impounded water and recreational usage.

The Papillion Creek project consists of 21 authorized reservoirs located west of Omaha, Nebraska. The siting plan of the 21 reservoirs is shown in Fig. 1. The Salt Valley Watershed flood control reservoirs, shown in Fig. 2, are located near Lincoln, Nebraska. The limnology of

[1] Abridged and updated from the Reconnaissance Report on Papillion Creek Reservoirs, U.S. Army Engineer District, Omaha, Corps of Engineers, Omaha, Nebraska, 1970.

these reservoirs being investigated by the Department of Zoology and Civil Engineering at the University of Nebraska. The nearest reservoirs east of Papillion Creek are located in western Iowa. Due to the lack of available data on these reservoirs, the four recreational reservoirs shown in Fig 3 were evaluated specifically for this report. By studying the weed infestation and limnology of the Nebraska and Iowa reservoirs, located approximately 50 miles on either side of Papillion Creek, correlations were drawn relative to aquatic weed growth potential of the authorized Papillion Creek Reservoirs.

DESCRIPTION OF RESERVOIRS

Flood Control Reservoirs near Lincoln

A water quality and eutrophication study on four flood control reservoirs in the Salt Valley Watershed district has been in progress since June 1968. Three of these reservoirs are eutrophic to the extent that blue-green algal blooms in open water and extensive weed growth in the littoral zone have interferred significantly with their recreational usage.(1).

The physical and chemical water quality data are given in Table I. Of particular importance are the concentrations of nitrogen and phosphorus in the water. These plant nutrients are available in amounts sufficiently high to support excessive weed and algal growth.

A summary of the algae and aquatic plants found in these reservoirs are listed in Table III. The dominant algae are indicative of eutrophic waters. The weeds consist of a variety of pondweeds common of fertile littoral areas.

Wagontrain is a long narrow reservoir oriented in a north-south direction. The flat surrounding terrain exposes the water surface to strong winds. The reservoir is continuously mixed and does not stratify. The water is turbid with suspended soil and detritus from the bottom. The high turbidity creates a light-limiting aquatic environment which prevents weed growth and inhibits algal growth. The turbidity adversely affects the recreational activities of swimming and fishing.

Stagecoach is a round-shaped reservoir seven miles southwest of Wagontrain. The reservoir is somewhat sheltered from the wind. The suspended solids present in the spring settle out in early summer reducing the turbidity of the water; however, the reservoir does not stratify. The sunlight and nutrient conditions promote luxuriant aquatic plant and algal growth. The general aesthetics of the reservoir by midsummer are poor. Swimming at this reservoir is reported to be poor. The general aesthetics for picnicking are reduced due to the unsightly weed growth and odors from decaying plants. Fishing is virtually impossible from the shore due to weed growth in mid to late summer.

Pawnee and Branched Oak are larger reservoirs situated in relatively flat terrain exposed to the wind. Due to their greater size, the suspended solids settle out early in the spring permitting light penetration. These reservoirs are continually mixed with only very brief, transient periods of stratification. Rooted weeds grow from depths of 14 feet and protrude from the water surface. Diatoms and green algae are abundant in early spring and blue-green blooms persist during July, August and September. Fishing is presently good; however, future fishing may be adversely affected by the highly eutrophic conditions. The excessive weed growth and severe blue-green algae blooms interfere with swimming. The appearance of the reservoir and production of malodors are nonaesthetic.

The general charateristics of the flood control reservoirs near Lincoln, Nebraska are summarized in Table V.

Recreation Reservoirs in Western Iowa

The physical and chemical water quality data from the sampling conducted on July 11-12 are listed in Table II. In general, the water quality in these reservoirs is similar to water quality in the reservoirs near Lincoln with the exception of turbidity and plant nutrients. Even though the nitrogen and phosphorus concentrations in Table II are above the desirable fertilization levels, they are significantly lower than the nutrient levels existing in the Nebraska reservoirs. Two of the Iowa reservoirs were very high in turbidity caused by suspended clay and silt. All of the Iowa reservoirs were stratified at the time of sampling in contrast to the virtually completed mixing conditions of the Nebraska reservoirs. Stratification has a significant influence on the biology of a lake.

Anita is the most desirable of the reservoirs studied. Even though the water had a light brown hue, its clarity made it very appealing for all forms of water recreation. The absence of dominant algal species and the presence of a high diversity of plankton indicates a water of desirable quality. Table IV lists the species of algae and rooted aquatic plants found in the Iowa reservoirs. All of the Iowa reservoirs with the exception of Anita had dominant blue-green algae populations present.

The dissolved oxygen and temperature profiles for Anita are shown in Fig. 4. The stratification is readily evidence by the rapid drop in dissolved oxygen with depth. The lack of mixing by wind action can be attributed to shelter provided ., the hilly terrain and the short reaches of water surface exposed to the wind.

Viking is sited in a relatively deep valley protected from the wind by forested hills. The dissolved oxygen and temperature profiles in Fig. 5 show the abrupt stratification existing at the time of sampling. The epilimnion was 28 to 30°C and 1 to 2 meters in depth. The epilimnion was turbid and green as a result of blue-green algae blooms. The hypolimnion was clear. The bottom 1 to 3 meters of the hypolimnion was anaerobic and had a strong hydrogen sulfide odor.

Aquatic weed growth extended from a depth of 14 feet and protruded from the water surface. However, due to the steep-sloping bottom, the water surface covered by weed growth was limited to the shoreline. The bathing beach had been treated to kill weed growth. Viking exhibited all the characteristics of a eutrophic lake, yet the natural beauty of the surrounding environment seedmed to offset the undesirable features - at least for the people swimming, boating and camping.

Prairie Rose exhibited several problems which plague small reservoirs. The concentrations of plant nutrients in the water were higher than the desirable levels (Table II). The water was turbid resulting from suspended soil. However, the turbidity was not great enough to produce a light-limiting condition preventing plant growth. The oxygen and temperature profiles are shown in Fig. 6. The epilimnion was a yellow green color resulting from suspended clay and algae (Table IV). The hypolimnion was brown with soil turbidity. Aquatic weeds were growing along the shore from depths of 4-5 feet. On September 9, Prairie Rose had a substantial blue-green algal bloom. In general the recreational conditions at Prairie Rose could be classified as fair.

Green Valley was very high in soil turbidity. The epilimnion was a brown-green color, and the hypolimnion was brown. The oxygen and temperature profiles are in Fig. 7. The turbidity prevented the growth of aquatic weeds, but was not sufficiently light-limiting to prevent moderate plankton growth in the surface water. Even though the reservoir was open to wind action, as evidenced by the installation of riprap along the shore, the reservoir was stratified at the time of sampling. Apparently the suspended silt and the temperature differential between the epilimnion and hypolimnion create a density differential sufficient for stable stratification. A study published by Moen[2] in 1956 classified Green Valley as a reservoir which had periods of temporary stratification. Green Valley could be classified as poor for fishing and fair for other recreational activities.

A summary of the general characteristics of the recreational reservoirs in western Iowa is given in Table VI.

PARAMETERS AFFECTING RESERVOIR WATER QUALITY

Plant Nutrients. In natural lakes, the limited supply of plant nutrients - commonly nitrogen and phosphorus - control aquatic plant growth. All of the reservoirs studied had excessive concentrations of these nutrients. For example, the generally accepted maximum level of orthophosphate in well-behaved lakes is less than 0.05 mg/1 as phosphate.

Siltation. Suspended silt and clay can inhibit light penetration and limit aquatic plant growth. Wagontrain and Green Valley are examples of reservoirs where excessive turbidity prevents nearly all weed growth. Prairie Rose is sufficiently turbid to suppress rooted aquatic weeds but not algae. High turbidity stifles fish life and it is not conducive to aesthetics or swimming.

Stratification. Complete mixing creates an ideal environmental for algal growth because all the nutrients in the water are potentially available to the algae. Consequently, the clear-water reservoirs in Nebraska have heavy blooms. On the other hand, complete mixing distributes the dissolved oxygen throughout the water profile. Stratification reduces the intensity of algal blooms by trapping nutrients in the hypolimnion. In a stratified eutrophic lake the hypolimnion may become anaerobic creating conditions adverse to fish. Viking is an ideal example of an eutrophic, stratified reservoir.

Algal Blooms. Heavy blue-green algal growths create nonaesthetic conditions, i.e., floating slimes, malodors, and green colored water.

All of the clear-water lakes with the exception of Anita have blooms of blue-green algae.

Aquatic Weeds. Aquatic weeds interfere with fishing, particularly from the shore, and boating in shallow water. They are hazardous to swimmers. Aquatic weeds can be controlled by chemicals and mechanical harvesting. Weed control is practiced in Iowa around bathing beaches, boat ramps and fishing points. However, overall weed control is expensive and may result in more serious algal problems.

Topography, Watershed and Climatic Conditions. The type of development on a watershed dictates to a significant extent the quality of the water entering a reservoir. Climatic conditions influence the entire limnology of a lake. The topography in association with the physical charateristics of the reservoir influences stratification. There are no significant differences in climatic conditions between eastern Nebraska and western Iowa. Therefore, the stratification of the Iowa reservoirs and lack of stratification of the Nebraska reservoirs is related to the following factors: the surrounding terrain, the shape and dimensions of the reservoir, and the quantity of suspended silt in the water.

PAPILLION CREEK RESERVOIRS

On the basis of the preliminary reconnasissance report, it can be said that the authorized Papillion Creek reservoirs will have many of the eutrophication problems identified in the existing reservoirs in eastern Nebraska and western Iowa. The following narrative is to a considerable extent guesswork due to the lack of study data on Papillion Creek.

First, assume that the impounded water will be rich in plant nutrients. This assumption is probably valid since the runoff water entering all of the existing reservoirs is from sub-basins supporting agricultural land use.

Second, assume that the water will be turbid and carry a significant silt load. This condition is indicated by Appendix VIII of the Review Report for Papillion Creek and Tributaries, Corps of Engineers, 1967.

Third, assume that the prevailing southerly winds will prevent stratification in the reservoirs oriented in a north-south direction.

Based on these assumptions we may deduce that the following conditions will exist at Papillion Creek reservoirs numbered 1, 2, 3, 4, 11, 15, 18 and 20 on Fig. 1. These eight reservoirs have a surface acre size that is comparable to reservoirs studied in eastern Nebraska and western Iowa.

Reservoirs numbered 1 and 11 will be turbid with limited stratification. Rooted weed growth and algae blooms will be minimized by lightlimiting conditions. Fishing will probably be poor, swimming fair and aesthetics fair.

Reservoirs 2, 4, 15, 18 and 20 because of their orientation will not be completely mixed by the wind. The turbidity of the water will probably decrease early enough in the growing season to allow significant weed growth. During the late summer when the reservoirs are stratified, substantial blue-green algal blooms will occur. The recreational conditions will be fair.

The water in Reservoir 3 will probably have low turbidity since reservoirs 1 and 2 will act as silt traps. Reservoir 3 will not stratify due to its orientation parallel to prevailing winds. Of the eight reservoirs discussed, this reservoir will have the most serious problems of weed infestation and blue-green algal blooms. Fishing will be good, while swimming and general aesthetics will be poor.

Turbidity, weed infestation and algal blooms are detrimental to swimming, fishing, boating, camping and picnicking. Unfortunately, there are few data that correlate the limnology of reservoirs and recreational water usage. Furthermore, very little information is available on the limnology of small lakes and reservoirs in the Great Plains. If the limnological characteristics of a proposed reservoir could be predicted, then it may be possible to design recreational facilities which would provide optimum benefits.

Currently there are no established design criteria and few precedents for the design of recreational facilities on eutrophic reservoirs. If a designer assumes an impounded water quality similar to a mountain lake, and the reservoir turns out to be very eutrophic, many of the recreational facilities will not be extensively used. A bathing beach located in a shallow bay may become weed infested. Picnic areas located on the leeward side of a reservoir during a severe blue-green algal bloom may become malodorous or generate a health hazard. Fishing points and boat ramps may be surrounded by weeds. Heavy silt concentrations or anaerobic conditions in the hypolimnion may reduce fishing.

PRELIMINARY PLAN OF PROCEDURE

Design criteria for recreational facilities at the proposed Papillion Creek reservoirs should be developed. Preliminary criteria can be based on conditions that exist at reservoirs which are limnologically similar to the proposed reservoirs. Final design criteria would provide guidelines for siting of swimming beaches, boat ramps, fishing points and picnic areas relative to the anticipated water quality. Preimpoundment site preparation may be necessary to reduce the adverse effects of eutrophic waters. To a considerable extent, design criteria for various water quality conditions can be established by visiting existing reservoirs with recreational facilities. The success or failure of the observed facilities can be correlated to the prevailing turbidity, weed and alage conditions.

Applications of empirically developed design criteria will require a prediction as to the limnological characteristics of the Papillion Creek reservoirs. Special studies will be required to predict the limnology of the proposed reservoirs. Preimpoundment limnological investigations should include stream water quality, algal assays of the eutrophication potential of the water, and an evaluation of wind mixing.

The stream water quality study on Papillion Creek would be performed by establishing gaging stations and sampling points at several of the proposed dam and reservoir sites. Quantity of flow, nutrient concentrations and silt load would be of primary concern.

The provisional algal assay procedures established by the Joint Industry/Government Task Force on Eutrophication[3] could be used to evaluate the eutrophication potential of the stream water.

A study on wind mixing should be performed to predict whether the Papillion Creek reservoirs will stratify. This study would consist of applying established wind wane theory [4, 5] to representative reservoirs examined for this report to determine their applicability. The most satisfactory formulas could then be used to evaluate the effect of wind action on the Papillion Creek reservoirs.

Two years of research has been conducted at the Salt Creek Reservoirs to determine the parameters of aquatic weed growth. The research was sponsored jointly by the University of Nebraska and the Salt Valley Watershed District. The research continued under support of the Nebraska Water Resources Research Institute and is conducted by Dr. Mark J. Hammer. Dr. Hammer is a consultant to the Omaha District and was senior investigator for this report.

TROPHIC STATE OF LAKES AND RESERVOIRS

Numerous workers (6,7) developed lists of algal species arranged in rank order of association with oligotrophic to eutrophic waters. Althouth these lists have some merit, particularly at the extremes, most forms have been shown to grow well over wide ranges of environmental conditions, making it impractical to use the species as definitive indicators of trophic state.

From the recognition of algal associations with various levels of nutrient enrichment came a series of trophic state indices based on phytoplankton assemblages. Thunmark (9) began with a ratio of the number of species of Chlorococcales to the number of species of desmids as a measure of the position of any plankton association in a series running from those characteristic of extremely unproductive soft transparent waters to extremely productive hard waters turbid with plankton.

A more current trend in lake classification is the employment of multiple parameter indices to quantitatively rank water bodies along a continuum of trophic state. Approaches vary from the six parameter relative trophic index developed at the Corvallis Environmental Research Laboratory to phytoplankton community-based trophic state indices that combine algal taxa, related chemical and physical associations, and community structure to produce a relative ranking of water bodies.

Principal components analysis has been used to further refine the selection of parameters indicative of trophic state and to reduce the dimensionality of a multivariate system to a single numerical expression. Once calculated, regardless of the technique, most of the numerical ranking indices are compared to traditional estimates of trophic state in order to judge their effectiveness.

Recently, 38 indices and measurements of trophic state were compared to evaluate their relative abilities to trophically rank a test set of 44 eastern and southeastern U.S. lakes and reservoirs (8). Some of the approaches included diversity and evenness components of diversity indices, loading models, N/P ratio, and single parameter indicators such as total Kjeldahl nitrogen and conductivity.

Phosphorus was used as a criterion because it is generally considered to be the most important nutrient associated with eutrophication of fresh waters, while chlorophyll is considered a primary parameter for measuring the manifestations of nutrient enrichment. Results from calculation of the various indices and measurements showed important differences relative to the two criteria. With the exception of total Kjeldahl nitrogen, which had agreement with both criteria, indices that correlated well with the phosphorus criterion showed poor rank correlation with the chlorophyll criterion. The converse was also true, i.e., those that correlated well with chlorophyll did poorly with total phosphorus.

Phosphorus loading models were quite successful in ranking lakes relative to the phosphorus criterion rankings but were unsuccessful when compard to the chlorophyll rankings, i.e., they did not predict the primary manifestation of eutrophication. Secchi disk depth measurements closely approximated the rank orders of the loading models. High mineral turbidity, which binds phosphorus in a form unavailable to the algae and reduces the light reaching them, constitutes the primary reason for the poor correlation of loading models and Secchi measurements with the chlorophyll criterion.

Such widely used biological indices as Palmer's Organic Pollution Index (10), Nygaard's Trophic State Indices (11), Shannon-Wiener's Phytoplankton Diversity Index (12), and Pielou's Evenness Component of Phytoplankton Diversity (13) were generally ineffective for lake trophic state assessment. However, several phytoplankton community-based trophic indices introduced in the study were shown to be more effective in trophically ranking lakes, relative to the chlorophyll a criterion, than most of the widely used trophic indices or measurements tested.

While eutrophication is the process of nutrient enrichment, the manifestations of nutrient enrichment present tangible problems to man. However, high nutrient loads to lakes and reservoirs (charaterized as eutrophic by any of the phosphorus criteria presented here) often do not result in either massive algal blooms or excessive submerged aquatic weed growths. This is attributed to light limitation due to mineral turbidity or other limiting factors. In reservoirs, a portion of the nutrient load may be short-circuited through the lower depths of the reservoir by project operations and be essentially unavailable for influencing reservoir water quality and biological productivity. The process of nutrient enrichment does not always result in the degradation of water quality. Whether or not the process adversely impacts water quality depends on the beneficial use for which a lake or reservoir is being managed and the degree of nutrient enrichment. Trophic classification of a lake reservoir becomes a function of the criteria used and is frequently inconsistent among existing classification criteria.

Trophic classification should be placed in proper perspective and the need for appropriate application of classification techniques should be recognized. Consistent application of a specific trophic classification technique to a single lake or group of lakes can reveal useful information concerning relative changes over time (trophic trend analyses). However, the limitations inherent in forcing lakes into categories with ill-defined limits--particularly when the limits are based upon single parameter--must be recognized and discretion used in application of such techniques. A more practical approach to reservoir classification would place paramount consideration upon the potential beneficial uses of the lake and, possibly, the regional water quality characteristics required to meet those uses.

These organisms photosynthesize and thereby provide both the structure and energy upon which much of the aquatic ecosystem depends; however, excessive populations, especially of undesirable species (e.g., blue-green algae), often interfere with man's use of water. Nuisance algal blooms occur in many Corps of Engineers (CE) impoundments due to excessive nutrient enrichment from various sources within their extensive watersheds. Excessive algal production and the subsequent decay of algal biomass often result in oxygen depletion, fish kills, disagreeable taste and odor problems in water supplies, and unsightly shorelines and surface waters.

Algal control measures are frequently considered to reduce excessive algal populations or to modify the species composition promoting the occurrence of more desirable forms. Numerous algal control and management techniques have been attempted with varying degrees of success.

Biological Control

A wide variety of biological control methods are available or are currently under development. These include the use of pathogens (e.g., viruses, bacteria, and fungi); control through the feeding activities of grazers (e.g., protozoans, zooplankton, and fish); and control by manipulating the interrelationships among plants, animals, and their environment (i.e., biomanipulation).

Pathogens potentially serve as highly potent and selective control agents. However, successful results have not yet been reported outside of the laboratory for this control technique.

Grazing, the most frequently attempted biological control technique, has not demonstrated conclusive results. However, protozoans and zooplankton appear to have potential as control agents.

Biomanipulation has shown promise as an effective algal control technique. The predominant mode of control appears to involve growth-inhibiting compounds, most of which are apparently excreted by algae or aquatic vascular plants. Additionally, the composition of algal populations can apparently be altered through the addition of chemicals (e.g., HC1, CO_2, and silica) that alter pH or offset specific nutrient limitations.

Biological methods offer a most desirable means of controlling nuisance algal problems. The requirements for success of introduced biological control organisms (pathogens and grazers) include high survival under a variety of conditions, an ability to reduce the population of the problem species, and the capability to coexist with native species. Biological control techniques are still in the early developmental stages, with most studies being conducted in the laboratory. Additional information is needed in all areas of biological control before widespread practical applications can be implemented.

Chemical Control

Algal control through the application of chemicals (algicides) is the most widely used technique. Application methods vary from dragging a bag of chemicals by boat to spraying them from a boat or helicopter. Results of most treatments have been somewhat inconsistent. Instances of unsuccessful results are probably most often due to incorrect dosages of the control chemicals. Proper dosage is difficult to determine because of the complicating influence of differences in water chemistry and hydrodynamics.

The most popular of the chemicals used to control algae are the copper compounds, especially copper sulfate. The use of copper compounds has recently been questioned due to their potential hazard when accumulated in bottom sediments and in associated organisms. Current research into new algicides has provided little advancement in the state of the art of chemical treatment. Some new compounds have been suggested, but their use is not widespread.

Physical Control

Physical methods of algae control include the mechanical removal of algae (harvesting); application of dyes (light limitation); the lowering of the water level (drawdown); the removal of bottom sediments (dredging); and the use of explosive charges to burst the vacuoles of blue-green algae (cellular disruption).

Mechanical harvesting has demonstrated limited success. However, serious technical difficulties exist due to the small physical size of most individual algal organisms. In general, this technique does not appear to be a practical method for in-lake application.

Dyes have been suggested to promote the limitation of algae by reducing light, but their use has not been widespread. The limited findings have been encouraging and suggest that this method may deserve further investigation.

Lake drawdown results in the immediate removal of algae. However, the long-term effectiveness of this technique is unknown. Further investigations are needed for a clear understanding of the effects of this technique. In multipurpose reservoirs this technique would not be practical in most cases because of conflicts with other project purposes.

Dredging is a frequently successful, but not a widely used, technique for controlling algae. This method is usually economically impractical except where it is implemented for other purposes (e.g., sedimentation control) as well.

Explosive charges have been used successfully for bursting the gas vacuoles of blue-green algae subsequently causing them to sink. However, the technique has obvious adverse effects on other aquatic organisms. Cellular disruption through the use of explosives is not considered a viable means to control algae in CE reservoirs.

SUMMARY AND CONCLUSION

Most algal control methods considered in this report are short term in nature and must be frequently repeated for continued success. More emphasis needs to be placed on determining specific causes of algal problems so that long-term effective control programs and, more importantly, preventive methodologies can be developed. The occurrence of most algal problems can usually be related to increased nutrient input (both internal and external) into a water body. Curbing these fluxes should ultimately result in long-term improvements in water quality and lessened algal growth. However, where such reductions are not possible or are ineffective, the judicious application of control techniques may be a necessity.

Many methods now used for algal control may not be acceptable for CE reservoirs. For example, algicides may have significant adverse ecological side effects. Furthermore, algicides, except for localized control, may be difficult to use in large reservoir projects; therefore, controlling algal blooms by reducing growth-promoting factors or through alterations in project operation are attractive alternatives. Previous algal control work has mainly been concentrated on natural lakes. However, reservoirs, in many cases, present significantly different conditions, including greater potential for management by manipulation of water levels and discharge elevations.

Specific recommendations based on this survey of algal control and management techniques are enumerated below:

a. There should be a change in emphasis from controlling algal problems after they arise to determining their causes and implementing a preventive program.

b. The application of chemicals, especially copper compounds, should be carefully monitored.

c. There is a need for improved phytoplankton surveillance and analysis programs using standardized techniques. Knowledge of the time course of development of algal blooms will allow the more prudent application of algicides.

d. Viral control of algae shows good potential; however, it still requires extensive research in order to characterize and isolate additional cyanophages, and study the nature of these unique host-parasite relationships.

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PAPILLION CREEK WATERSHED

Douglas, Sarpy, and Washington Counties, Nebraska

Site No.	Name	Drainage Area Sq. Miles	Lake Surface Area Acres
1	East Kennard	23.3	520
2	West Kennard	17.1	490
3	County Line	32.9	840
4	Washington	9.9	215
5	Elk City	3.2	72
6	168th Street	3.1	70
7	Highway 36	1.7	38
8	Bennington	2.8	63
9	Rainwood Drive	2.1	47
10	Thomas Creek	5.3	120
11	Irvington	17.1	450
12	Elkhorn N.W.	2.6	59
13	Chapel Hill	2.1	47
14	Elkhorn East	2.8	63
15	West Dodge	15.8	335
16	Military	6.0	130
17	Blondo	1.9	32
18	Millard	17.3	340
19	Gretna	4.4	125
20	Chalco	13.7	300
21	Papillion	3.9	78

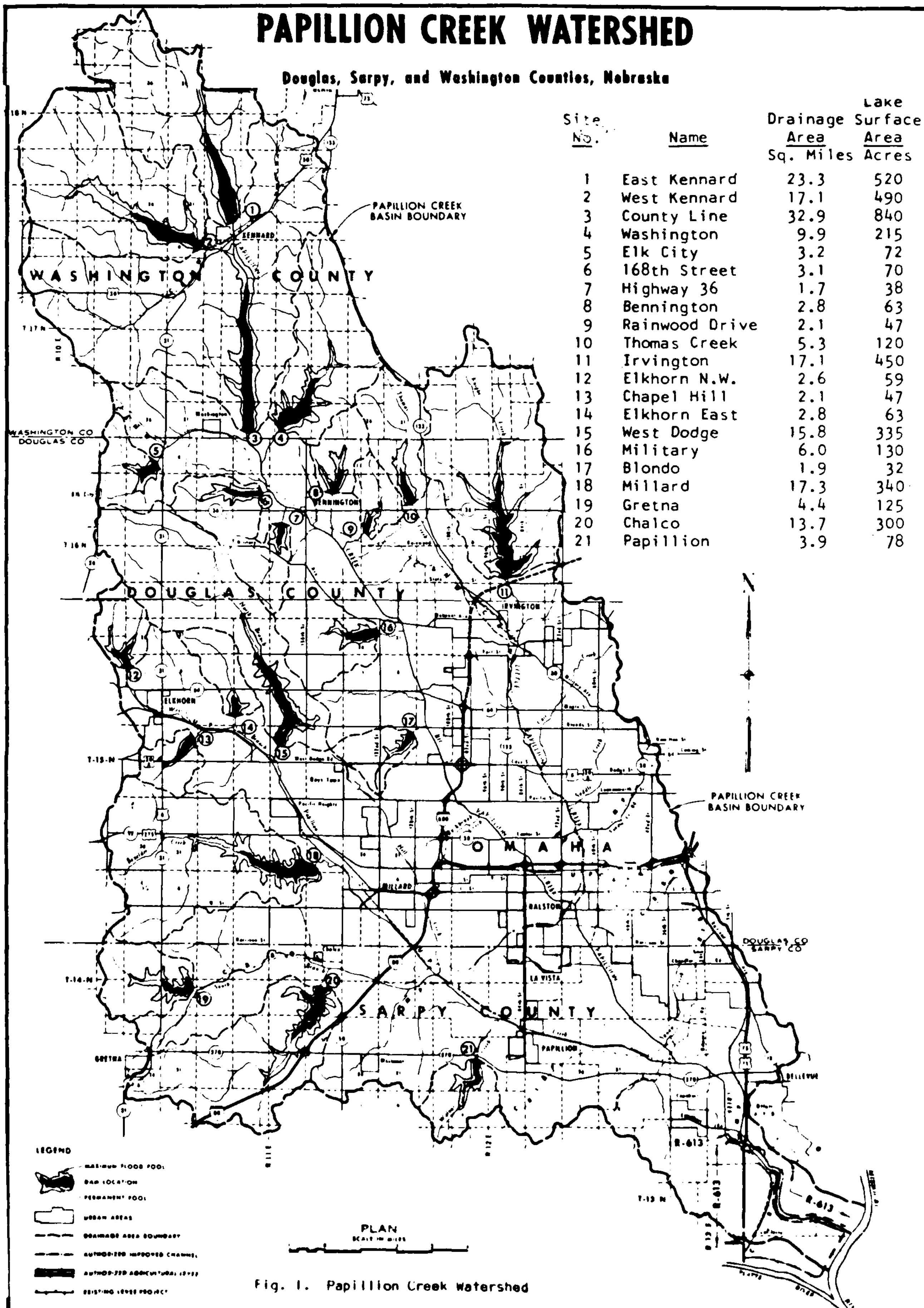
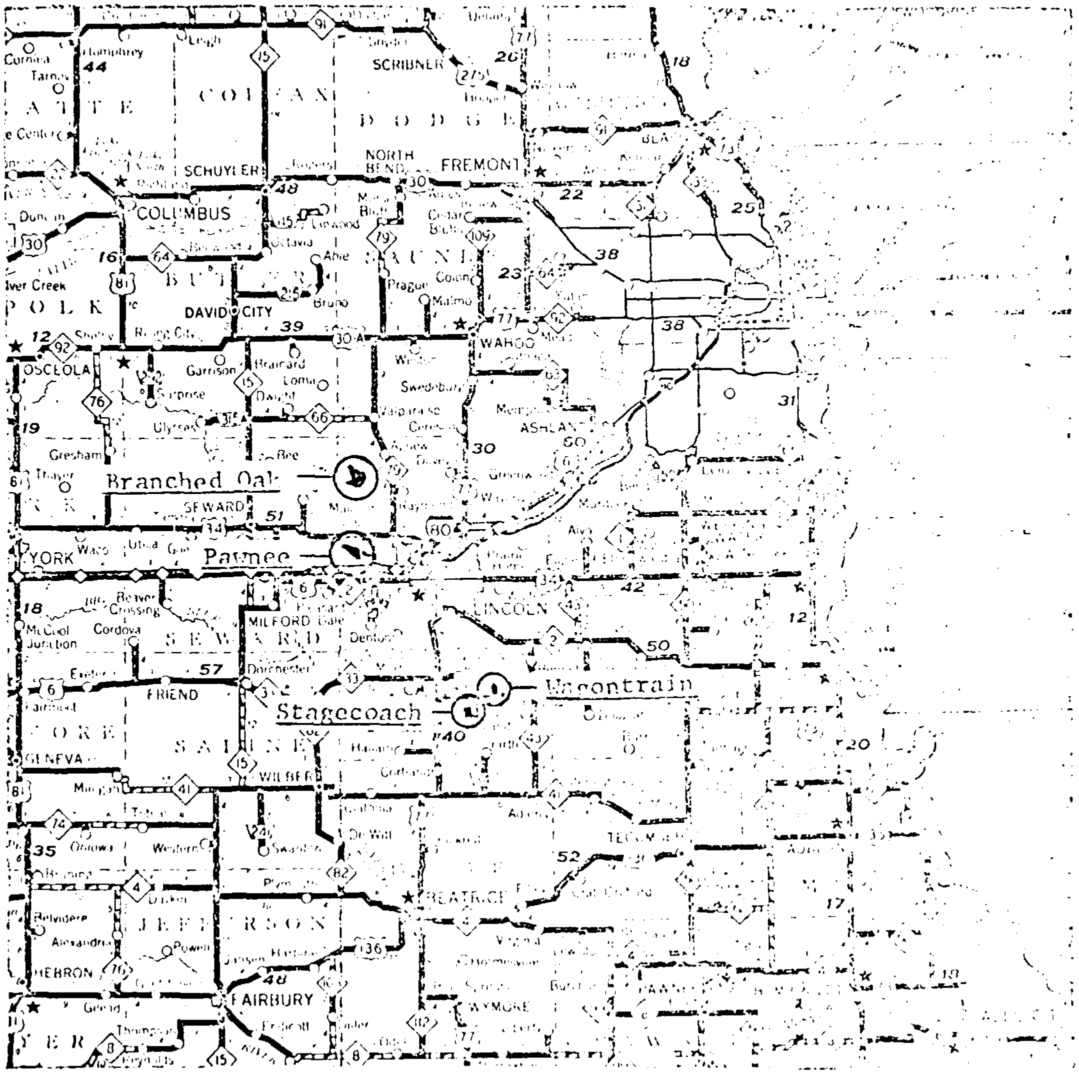
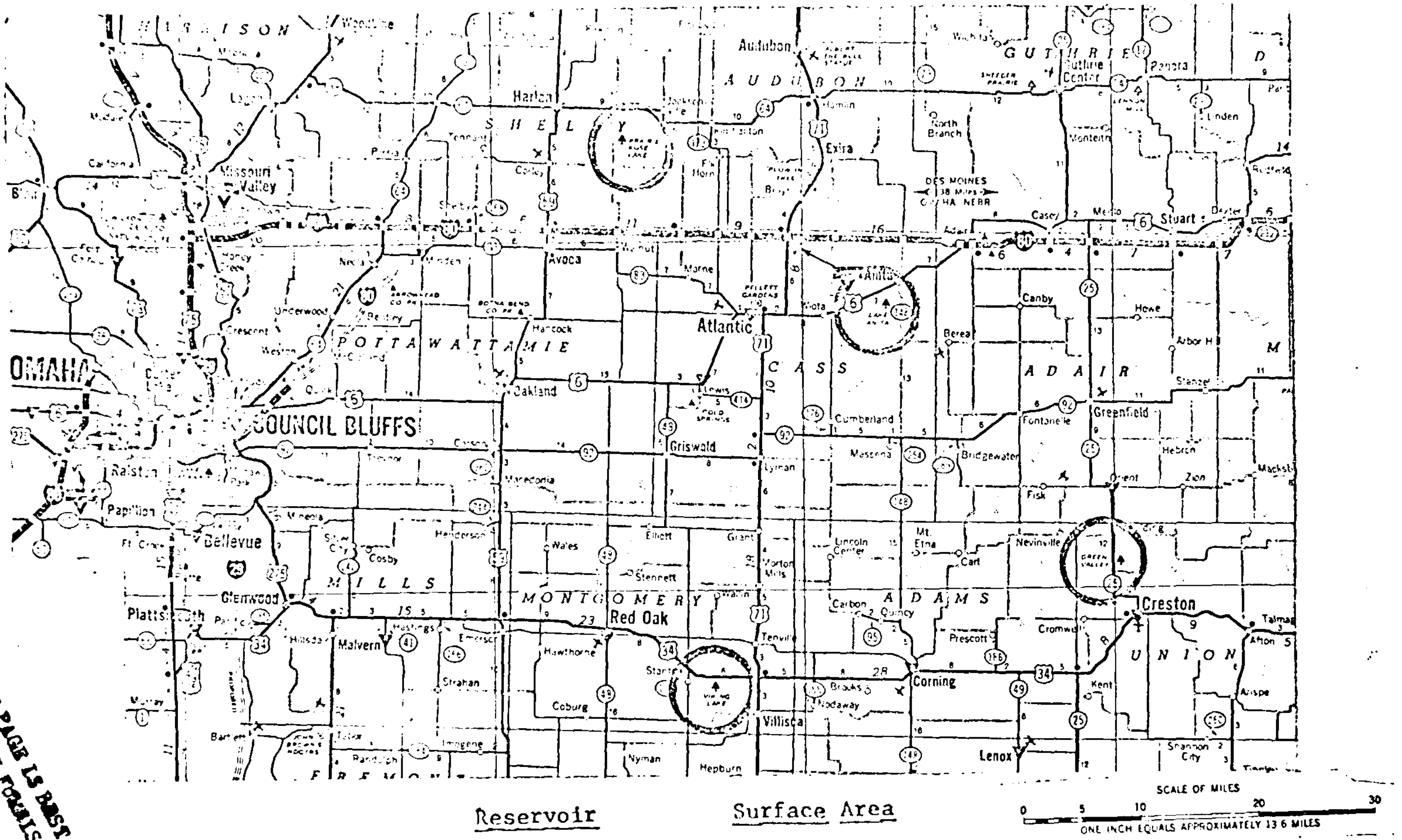


Fig. 1. Papillion Creek Watershed



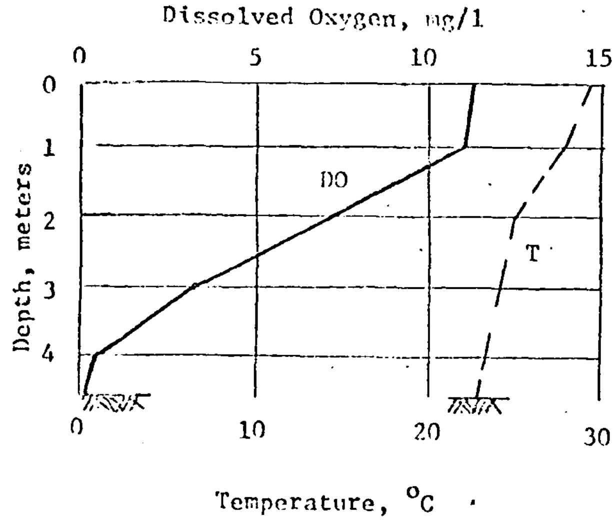
Reservoir	Surface Area
Wagontrain	315 acres
Stagecoach	170
Pawnee	740
Branched Oak	1300

Fig. 2. Location of flood control reservoirs near Lincoln, Nebraska.

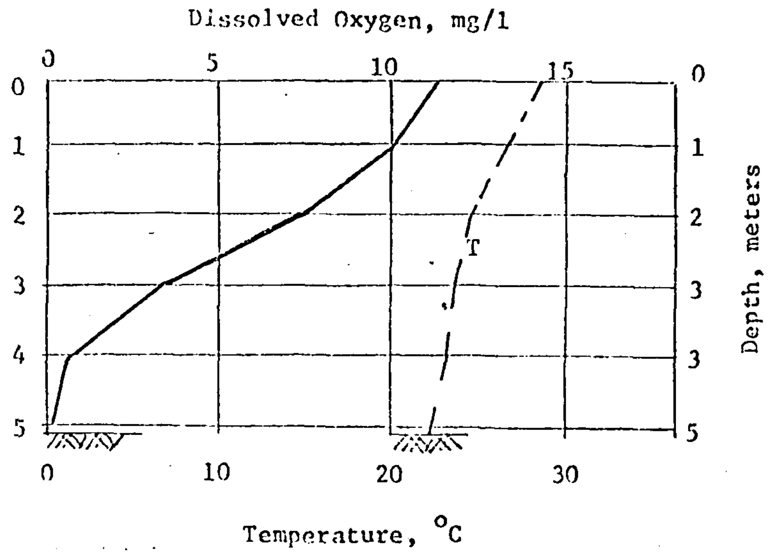


Reservoir	Surface Area
Prairie Rose	220 acres
Anita	170
Green Valley	1390
Viking	150

Fig. 3. Location of recreational reservoirs in western Iowa.



Station 1



Station 2

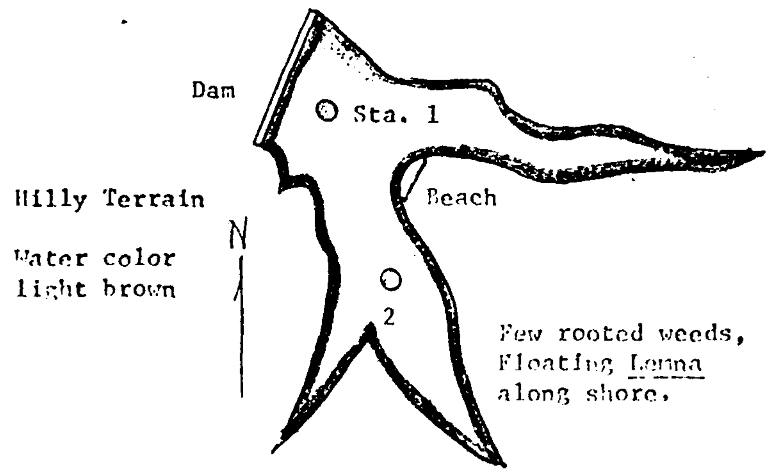
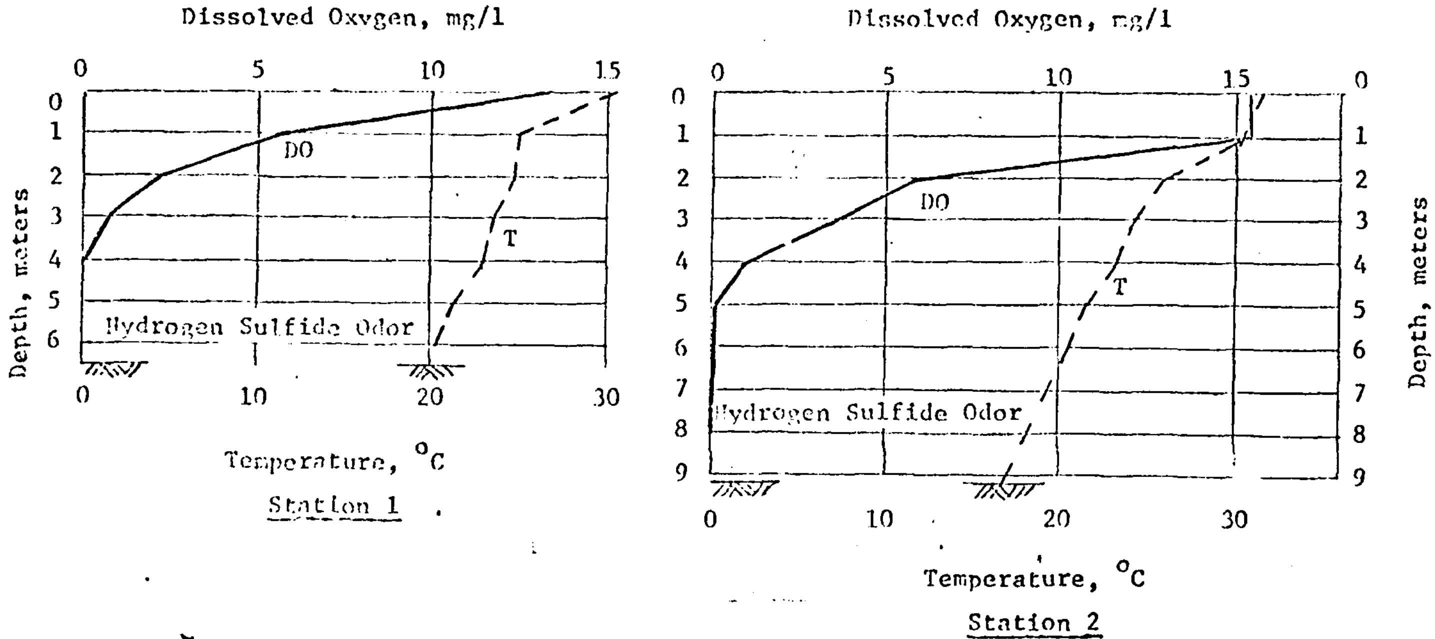


Fig. 4

Oxygen and Temperature Profiles, July 11, 1969

Anita, Iowa



Hilly Terrain

Water color green

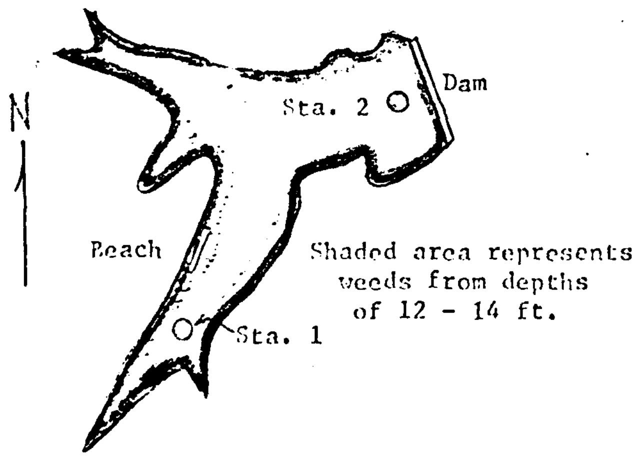


Fig. 5

Oxygen and Temperature Profiles, July 11, 1969

Viking , Iowa

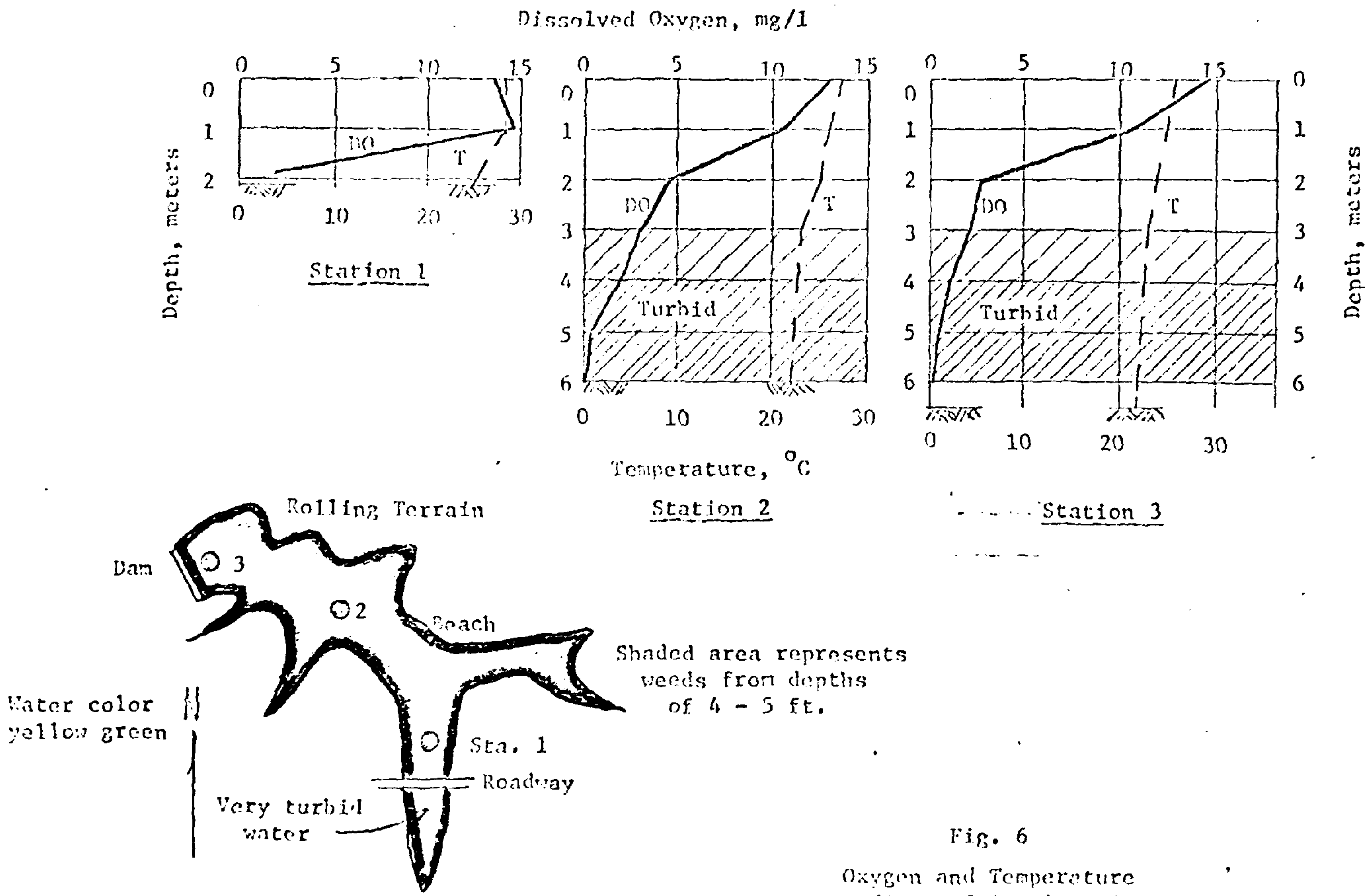


Fig. 6

Oxygen and Temperature Profiles, July 11, 1969

Prairie Rose, Iowa

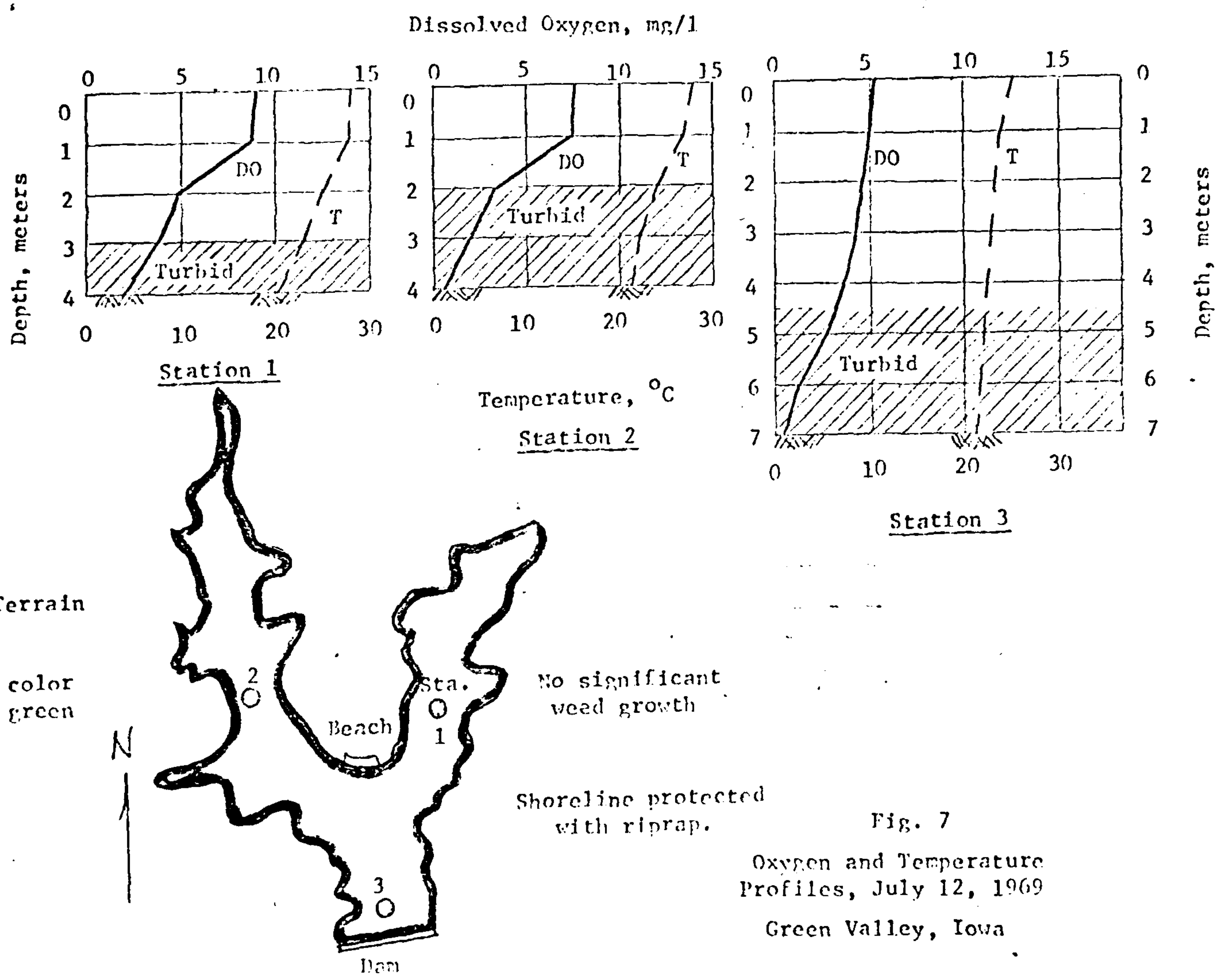


Fig. 7

Oxygen and Temperature
Profiles, July 12, 1969

Green Valley, Iowa

TABLE I

Physical and Chemical Water Quality Data, July 1969
Flood Control Reservoirs near Lincoln, Nebraska

	Wagontrain	Stagecoach	Pawnee	Branched Oak
Temperature Range, °C.	22.9-29.3	24.3-28.2	22.7-28.3	22.5-28.1
Turbidity, Jackson Units	140	17	12	20
Secchi Disc Range, ft-in.	0-6 to 1-10	2-0 to 5-11	4-1 to 10-0	4-0 to 12-11
Total Dissolved Solids, mg/l	223	251	200	326
Total Suspended Solids, mg/l	74	11	6	9
Dissolved Oxygen Range, mg/l	8.8-0.5	10.4-2.5	9.2-0.2	7.4-1.4
pH	7.84	8.33	8.27	8.10
Alkalinity, mg/l-$CaCO_3$	129	136	141	208
Total Phosphate, mg/l-PO_4	0.30	0.22	0.39	0.35
Ortho Phosphate, mg/l-PO_4	0.16	0.08	0.07	0.26
Iron, mg/l-Fe	0.60	0.26	0.17	0.13
Total Hardness, mg/l-$CaCO_3$	168	184	164	265
Calcium Hardness, mg/l-$CaCO_3$	91	101	83	150
COD, mg/l	—	—	—	—
Nitrate-Nitrogen, mg/l-N	1.35	0.08	0.22	0.21
Ammonia-Nitrogen mg/l-N	0.51	0.89	0.64	0.46
Organic-Nitrogen mg/l-N	0.25	0.32	0.31	0.51
Sulfate, mg/l-SO_4	29	24.5	14.4	45
Chloride mg/l-Cl	4.6	9.2	4.5	3.9

TABLE II

Physical and Chemical Water Quality Data, July 11-12, 1969
Recreational Reservoirs in Western Iowa

	Anita	Viking	Prairie Rose		Green Valley	
	composite	composite	epilimnion	hypolimnion	epilimnion	hypolimnion
Temperature, °C	23-29	17-31	26-28	22-23	24-28	21-23
Turbidity, Jackson units	10	29	100	220	33	188
Secchi Disc, ft.-in.	6-6	2-4	2-6		1-6	
Total Dissolved Solids, mg/l	191	165	163	411	167	314
Total Suspended Solids, mg/l	4	8	70	133	19	117
Dissolved Oxygen, mg/l	0.2-11	0-15	3-14	0.1-3	5-9	0.2-4
pH	8.3	8.2	8.8	8.0	8.3	8.1
Alkalinity, mg/l-Ca CO_3	122	92	128	116	86	78
Total Phosphate, mg/l-PO_4	0.11	0.22	0.12	0.18	0.17	0.27
Ortho Phosphate, mg/l-PO_4	0.04	0.10	0.04	0.11	0.09	0.19
Iron, mg/l - Fe	0.18	0.19	0.54	0.72	0.37	0.54
Total Hardness, mg/l - Ca CO_3	148	100	144	124	116	108
Calcium Hardness, mg/l-Ca CO_3	96	62	80	78	76	70
COD, mg/l	42	106	38	15	182	19
Nitrate-Nitrogen, mg/l-N	0.5	0.4	0.7	0.9	3.3	3.3
Ammonia-Nitrogen mg/l-N	0.28	0.39	0.22	0.50	0.34	0.28
Organic-Nitrogen mg/l-N	0.39	0.78	0.50	0.34	0.28	0.28
Sulfate, mg/l-SO_4	6	5	5	5	37	14
Chloride, mg/l-Cl	4.0	6.5	5.0	4.5	6.5	5.5

TABLE III

Algae and Aquatic Plant Data, July, 1969

Flood Control Reservoirs near Lincoln, Nebraska

WAGONTRAIN

Algae

Dominant species

Melosira
Cyclotella
Trachelomonas
Lepocinclis
Euglena
Placus

Other species

Coelastrum
Anabaena
Aphanizomenon
Oocystis
Pandorina
Sphaerocystis

Rooted Aquatic Plants

Sagittaria (Arrowhead)

PAWNEE

Algae

Dominant species

Anabaena
Aphanizomenon
Microcystis
Fragilaria

Other species

Ceratium
Oocystis
Sphaerocystis
Dictyosphaerium
Trachelomonas
Caclastrum
Melosira

Rooted aquatic plants

Potamogeton americanus
Potamogetan pectinatus
Polygonum

STAGECOACH

Algae

Dominant species

Microcystis
Anabaena
Aphanizomenon

Other species

Trachelomonas
Eudorina
Sphaerocystis
Melosira
Coelastrum
Pediastrum
Oocystis
Ceratium
Staurastrum

Rooted Aquatic Plants

Potamogeton pectinatus
Potamogeton americanus
Najas
Polygonum

BRANCHED OAK

Algae

Dominant species

Aphanizomenon
Sphaerocystis

Other species

Microuptis
Pediastrum
Ceratium
Melosira
Eudorina
Coelastrum
Mallomonas
Euglena
Fragilaria

BRANCHED OAK (Cont.)

Rooted aquatic plants

Polygonum
Potamogetan pectinatus
Potamogetan americanus
Vallisneria

TABLE IV

Algae and Aquatic Plant Data July 11-12, 1969

Recreational Reservoirs in Western Iowa

ANITA

Algae

No Dominant species

Pediastrum	Staurastrum
Ceratium	Trachelomonas
Dinobryon	Lepocinclis
Oocystis	Coelastrum
Asterococcus	Actinastrum
Melosira	Nitschia
Schroederia	Selenastrum
Scenedesmus	Nephrocytium
Anabaena	Cosmarium
Sphaerocystis	Chordatella
Eudorina	Mallomonas
Microcystis	Volvox

Floating Aquatic Plants

Lemna

PRAIRIE ROSE

Algae

Dominant species

Microcystis

Other species

Anabaena	Trachelomonas
Pediastrum	Aphanizomenon
Ceratium	Closterium
Fragilaria	Euglena
Melosira	Sphaerocystis
Asterionella	Oocystis
Coelastrum	Asterococcus

Ro Rooted Aquatic Plants

Potamogeton fectinatus (Sago Pondweed)

VIKING

Algae

Dominant species

Anabaena
Microcystis

Other species

Aphanizomenon
Cosmarium
Ceratium
Staurastrum
Pediastrum

Rooted Aquatic Plants

Potamogeton americanus (Pondweed)
Potamogeton fectinatus (Sago Pondweed
Najas (Bushy Pondweed)
Anacharis canadensis (Waterweed)

GREEN VALLEY

Algae

Dominant species

Microcystis
Aphanizomenon

Other species

Coelastrum
Closterium
Sphaerocystis
Eudorina
Lepocinclis
Oocystis
Asterococcus
Melosira

Rooted Aquatic Plants

Trace of Sagittaria
Trace of Potamogeton pectinatus (Sago Pondweed)

TABLE V

General Characteristics During Late Summer
Flood Control Reservoirs near Lincoln, Nebraska

	WAGONTRAIN	STAGECOACH	PAWNEE	BRANCHED OAK
Physical Features				
Surface area, acres	315	170	740	1300
Shape	long and narrow	round	oblong	round (branched)
Terrain	flat	rolling	flat	flat
Stratification	transient	none	transient	transient
Water Conditions				
Color	grey-brown	green	green	green
Source of turbidity	soil and detritus	algae	algae	algae
Algae and Aquatic Weeds				
Algae growth	moderate	heavy	heavy	heavy
Blue-green algal blooms	none	severe	severe	severe
Rooted weeds	few	heavy to 12 ft. depth	heavy to 14 ft. depth	heavy (developing)
Recreational Conditions				
Swimming	fair	poor	fair	fair
Fishing	poor	good	good	good
Aesthetics	fair	poor	fair	fair

TABLE VI

General Characteristics During Late Summer
Recreational Reservoirs in Western Iowa

	ANITA	VIKING	PRAIRIE ROSE	GREEN VALLEY
Physical Features				
Surface area, acres	170	150	220	1390
Shape	irregular-narrow	irregular-narrow	irregular-narrow	wide branches
Terrain	hilly	hilly	rolling	flat
Stratification	yes	yes	yes	yes
Water Conditions				
Color	light brown	green	yellow-green	brown-green
Source of Turbidity	dissolved organics	algae	soil and algae	soil
Algae and Aquatic Weeds				
Algae growth	light to moderate	heavy	moderate to heavy	light
Blue-green algal blooms	possible	severe	substantial	none
Rooted weeds	few	heavy	some	none
		12 ft. depth	4 ft. depth	
Recreational Conditions				
Swimming	excellent	fair	fair	fair
Fishing	good	good	good	poor
Aesthetics	good	good	fair	fair

END

DATE

ILME